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Opening the Operating Window of Impulse Drying: III. Controlled Decompression Experiments

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OPENING THE OPERATING WINDOW OF IMPULSE DRYING: III. CONTROLLED DECOMPRESSION EXPERIMENTS

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ABSTRACT

Recent Institute research has shown that changes in the nip opening process can significantly impact sheet delamination during impulse drying. Empirical evidence shows that by opening the nip to ambient pressures in excess of one atmosphere delamination can be avoided. While this method may prove to be practical, methods that were easier to implement are being sought.

Further experimental work showed that by properly controlling the load applied to the sheet as the nip opens sheet delamination could be inhibited. The experiments identified nip opening load conditions that were sufficient to suppress the delamination of 205 g/m^2 linerboard handsheets, having a freeness of 400 ml CSF at 35% ingoing solids.

EXPERIMENTAL

Controlled Decompression Impulse Drying

Based on the Institute's previous research,[1-4] experiments were performed to assess the idea of controlling the decompression of the sheet during the nip opening process. In this concept, the ambient pressure surrounding the impulse dryer would be maintained at one atmosphere (101 kPa absolute), while the nip opening pressure profile would be modified by adding a long decompression to the standard nip pressure profile. For simplicity, this long decompression is referred to as a "ramp profile" in the discussion that follows.

The shape of the ramp profile is defined by the applied load pressure at the instant that the nip begins to open and the time at which the applied pressure equals the ambient pressure, and the functional relationship between applied pressure and time. Figure 1 shows the ramp profiles that were investigated.

Using the same handsheets as were used by Krause,[1,3] a series of impulse drying experiments were performed in which all conditions were maintained constant, except for the ramp profile and the platen set-point temperature. Table 1 shows the parameters that were fixed during these experiments.

Figure 2 shows outgoing solids as a function of platen set-point temperature. It should be noted that the ramp profile adds to the total impulse applied to the sheet. Hence, it is understandable that outgoing solids increased when the ramp profile was changed from the absence of a ramp (NO RAMP) to the longest ramp (RAMP A).

The impulse dryed sheets were tested using out-of-plane ultrasound. The coefficient of variation of the specific elastic modulus was determined and is shown plotted as a function of platen set-point temperature and ramp profile in Figure 3. In agreement with all earlier work, delaminated sheets were found to have coefficients of variation in excess of between 10 and 15%. Review of Figure 3 showed that sheets impulse dried with no ramp profile delaminated at all platen set-point temperatures investigated. Samples impulse dryed using Ramp "C" failed to delaminate only at the lowest platen set-point temperature of 200°C, while ramps "B" and "A" did not delaminate at any of the platen set-point temperatures investigated.

Figure 4 shows specific elastic modulus as a function of platen set-point temperature. It was observed that sheets impulse dried with ramp profiles that prevented delamination had improved strength relative to any other condition investigated.

Hence, by using the proper ramp profile, the press surface temperature may be increased to obtain higher sheet strength as well as higher solids.

Measurement Of Internal Sheet Temperature

In additional experiments, which were otherwise identical to those presented in the last section, the sheets were formed from three equal layers with 0.051-mm diameter thermocouples between layers and on the top and bottom surfaces of the sheet.

Figures 5 through 8 show these experimental temperature profiles. The temperature on the heated surface of the sheet is designated as T1, those between sheet layers as T2 and T3, and on the surface of the sheet in contact with the felt as T4. The platen set-point temperature, as measured and maintained constant by a thermocouple on the backside of the platen, is designated as Ts.p. The instantaneous platen surface temperature, as measured by a vacuum deposited thermocouple, is designated as Tp.s.

A number of important observations can be made from the experimental temperature profiles. These are

1. The temperature at the interface between the top layer and middle layer of the sheet generally tended to decrease with time during the nip opening process. This is consistent with evaporative cooling.

2. At any given time during nip opening, sheet temperature decreases with increasing depth into the sheet. Hence, it is anticipated that flashing and venting would occur from the top surface of the sheet downward.

3. During nip opening, the internal sheet temperatures often went through a period where the temperature increased before following the general decreasing trend. This temperature increase occurs while the system is still a subcooled liquid.

Interpretation Of The Internal Sheet Temperature Data

Referring to the experimentally determined internal sheet temperatures, Figures 5 through 8, and the experimental transition times reported in Table 2, we may identify regions of the experimental temperature profiles as being at saturation conditions. Hence, the internal temperature measurements can be used as a measure of the local internal sheet pressure. This was done by calculating these local pressures as the saturation pressures corresponding to the measured temperatures for the experiments as shown in Figures 9, 10, and 11. Also shown in the figures, for comparison, are the corresponding load decompression profiles.

The pressure differential across the top ply of the sheet may be calculated as P2-Load Pressure. The maximum pressure differential and its time of occurrence are reported in Table 3. These measurements may be used as a test of the hypothesis that a sufficient pressure imbalance causes delamination. We observe that a pressure imbalance of about 200 kPa occurred for the RAMP=NO 260°C case, while there was no imbalance of pressure observed in the RAMP=A cases for 260°C. As the RAMP=NO 260°C case delaminated, while the RAMP=A cases did not, we support the hypothesis that the long ramp prevents delamination by reducing the imbalance between internal sheet pressure and the load pressure. Further experiments along these lines are needed to fully understand this delamination mechanism.

CONCLUSIONS

This work demonstrated that delamination could be inhibited by applying a controlled decompression during nip opening. Internal sheet temperature profiles were converted to pressure profiles, and pressure imbalances were determined. The results are in agreement with the hypothesis that delamination results from a pressure imbalance between the inside and outside of the sheet during nip opening.

REFERENCES

1) Krause, A.M., The Effect of Ambient Pressure on Sheet Delamination in Impulse Drying, M.S. Thesis, Institute of Paper Science and Technology, 1995.

2) Orloff, D. I; Patterson, T.; Krause, A. M.; "Method and Apparatus for Drying a Fiber Web at Elevated Ambient Pressures", United States Patent Number 5,598,642, Issued February 4, 1997.

3) Orloff, D. I.; Patterson, T.; Krause, A.M. "Opening the Operating Window of Impulse Drying - I. The Effect of Ambient Pressure at Nip Opening," 1997 TAPPI Engineering and Papermakers Conference, October 6-9, 1997, Nashville, TN.

4) Orloff, D. I.; Patterson, T.; Parviainen, P. M. Opening the Operating Window of Impulse Drying - II. Pressure Differential as a Source Of Delamination," 1997 TAPPI Engineering and Papermakers Conference, October 6-9, 1997, Nashville, TN.

ACKNOWLEDGEMENT

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TABLES

Table 1. Fixed Parameters.

Pulp:	Species	93% southern hard pine, 7% gum
	Kappa #	102
	Weight Weighted Fiber Length	2.3 mm
Sheet:	Basis Weight	205 g/m^2
	Ingoing Solids	34%
	Ingoing Density	0.7 g/cm^3
	Freeness	400 ml, CSF
	Hydrodynamic Specific Surface	29.5 m^2/g
	Hydrodynamic Specific Volume	0.823 cm^3/g
	IngoingTemperature	85°C
Felt:	Sample Designation	BXC5
	Ingoing Moisture	16%
Impulse Drying:	Platen Material	Carbon Steel
	Peak Nip Pressure	4300 kPa
	Nip Dwell Time	40 ms

Table 2. Experimental Transition Times From Subcooled Liquid to Saturated Mixture for the Ramp Experiments.

Case	Experimental Transition Time At Position 2 Between First And Second Layer, s
NO/200°C	>0.019
NO/260°C	0.005
A /200°C	0.060
A/260°C	0.010

Table 3. Mean Pressure Difference at the End of the Ramp.

Case	Maximum Pressure Differential, KPa (absolute)	Time of Maximum Pressure Differential, s
A/200°C	0	na
NO/260°C	200	0.014
A/260°C	0	na

ILLUSTRATIONS

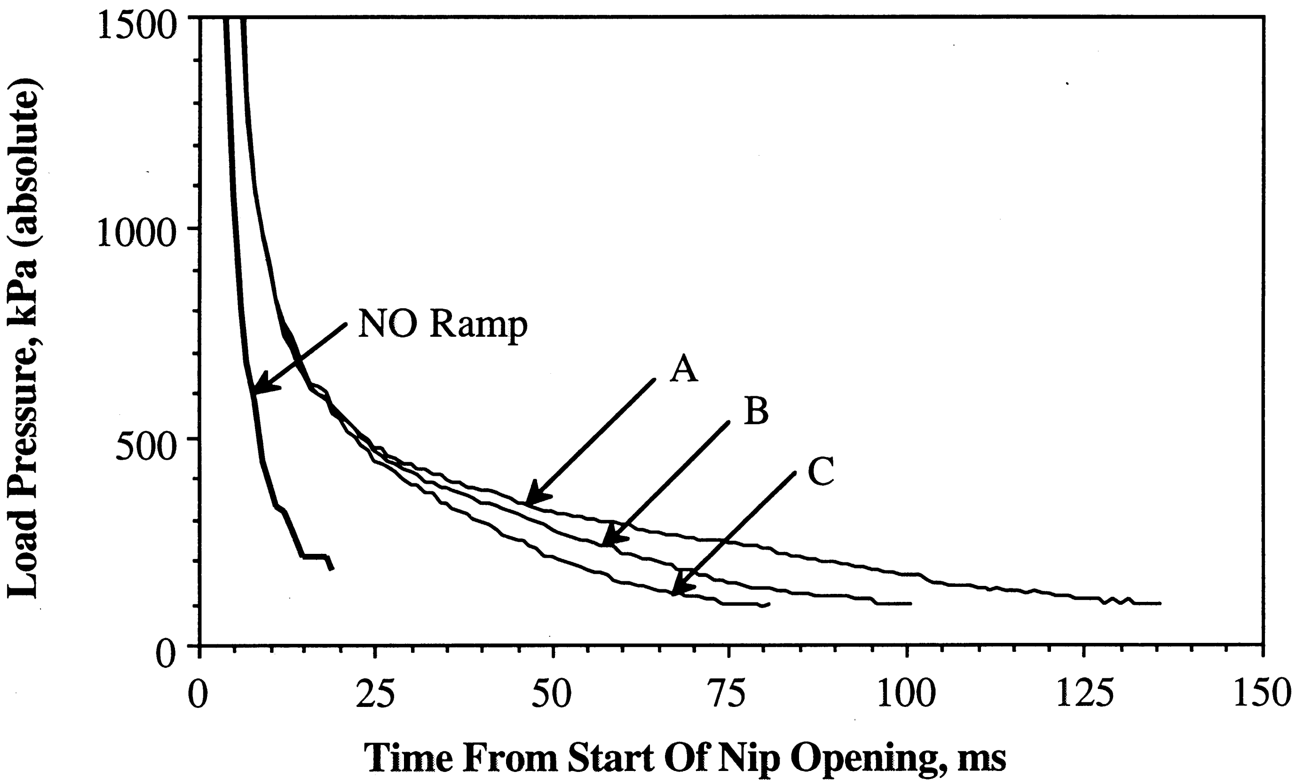

Figure 1. Nip Opening Decompression Profiles.

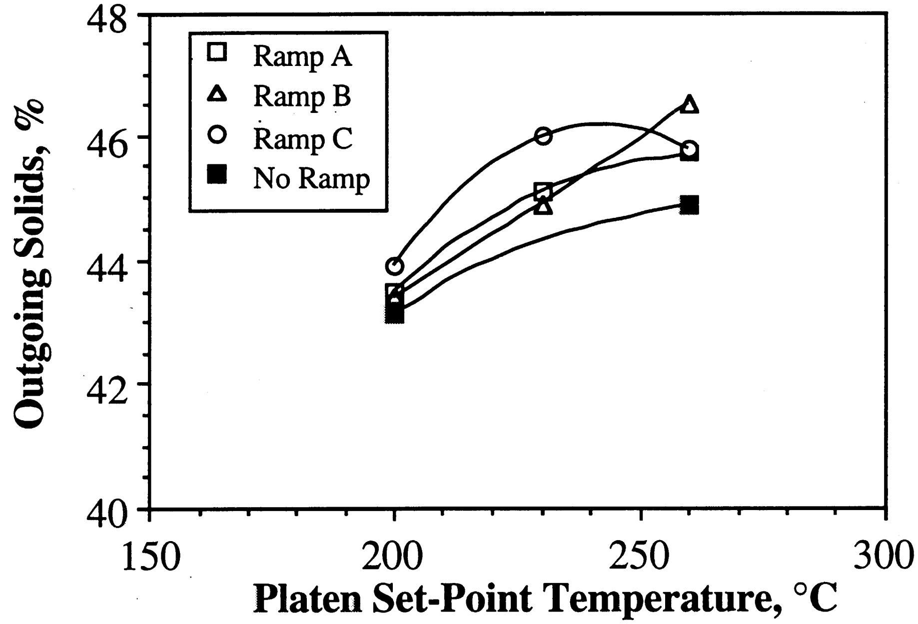

Figure 2. Outgoing Solids as a Function of Platen Set-Point Temperature for Nip Opening Ramp Profiles.

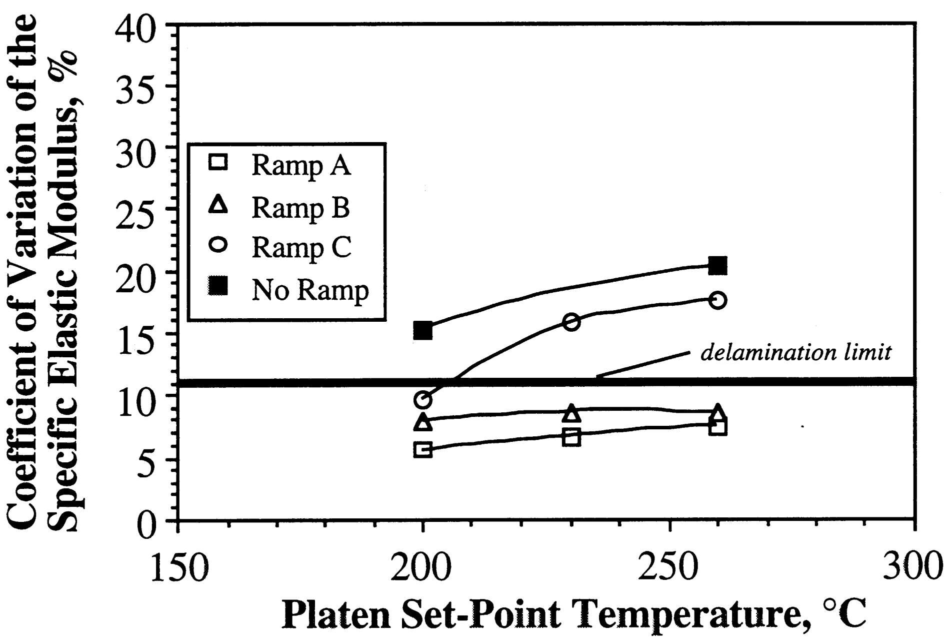

Figure 3. Coefficient of Variation of the Specific Elastic as a Function of Platen Set-Point Temperature for Nip Opening Ramp Profiles.

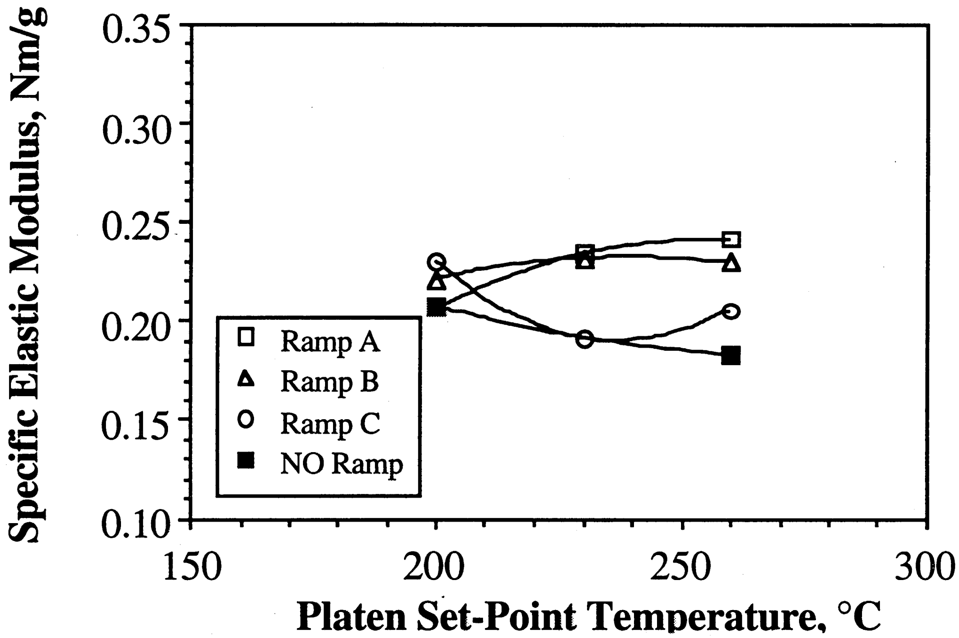

Figure 4. Specific Elastic Modulus as a Function of Platen Set-Point Temperature for Nip Opening Ramp Profiles.

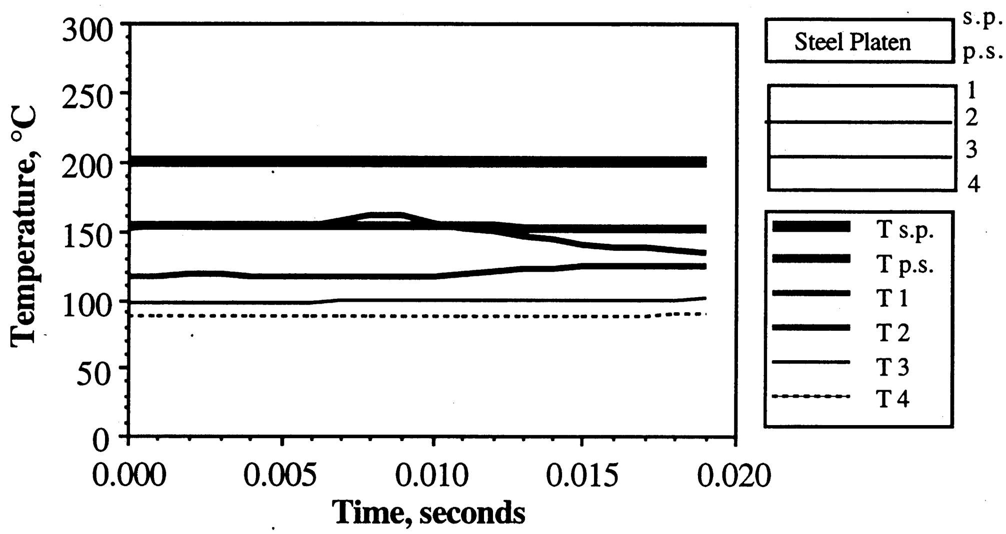

Figure 5. Measured Temperature as a Function of Time During Nip Opening Using Ramp=NO at a Set-Point Temperature of 200°C.

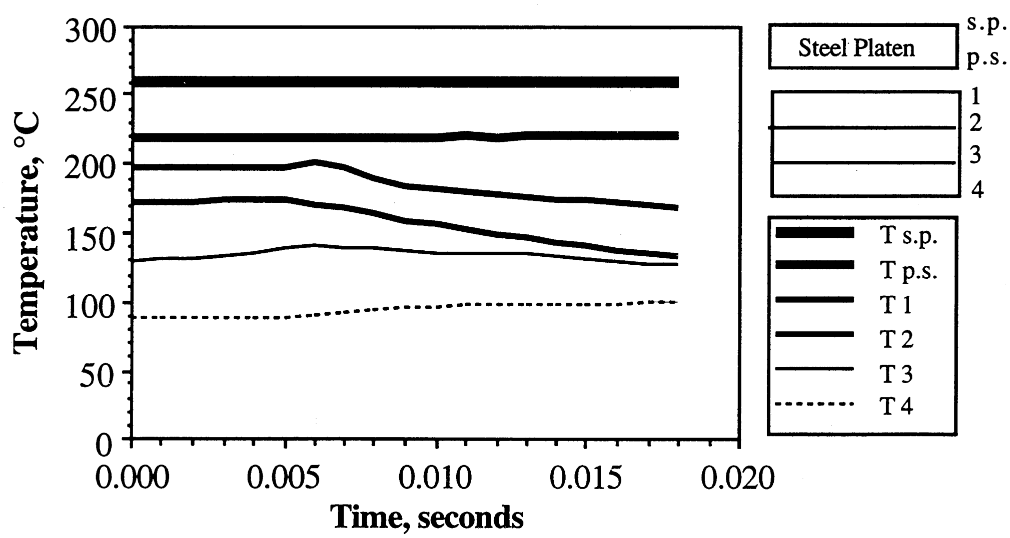

Figure 6. Measured Temperature as a Function of Time During Nip Opening Using Ramp=NO at a Set-Point Temperature of 260°C.

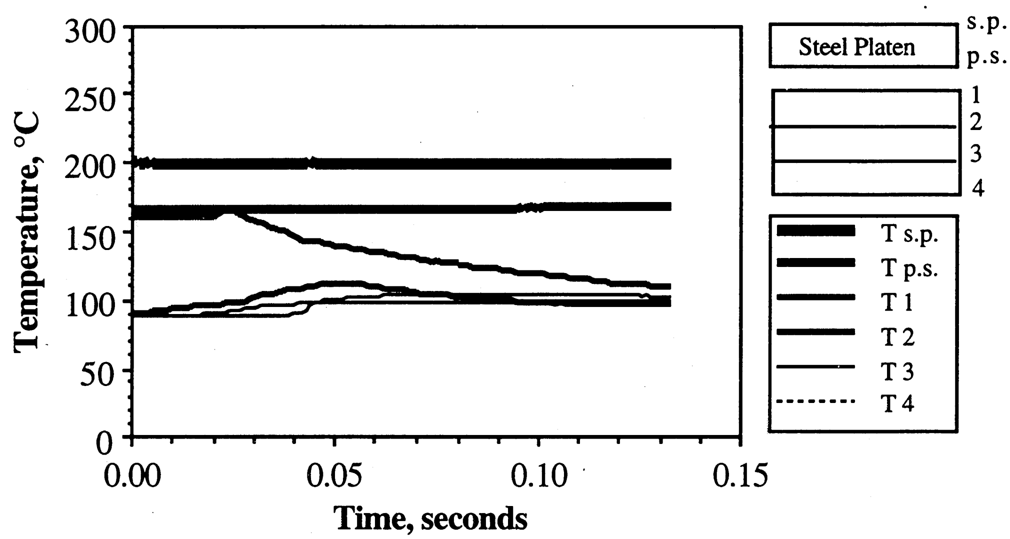

Figure 7. Measured Temperature as a Function of Time During Nip Opening Using Ramp=A at a Set-Point Temperature of 200°C.

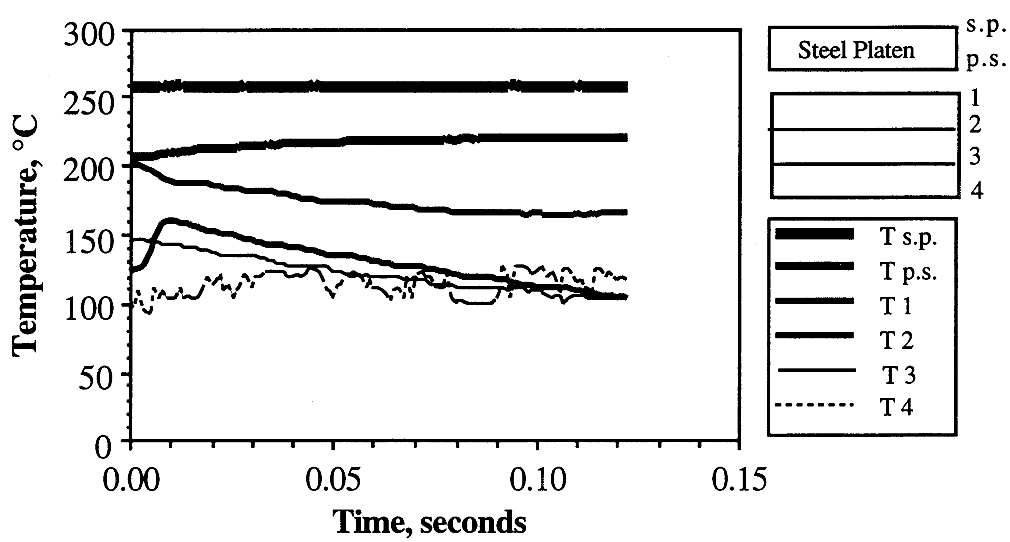

Figure 8. Measured Temperature as a Function of Time During Nip Opening Using Ramp=A at a Set Point Temperature of 260°C.

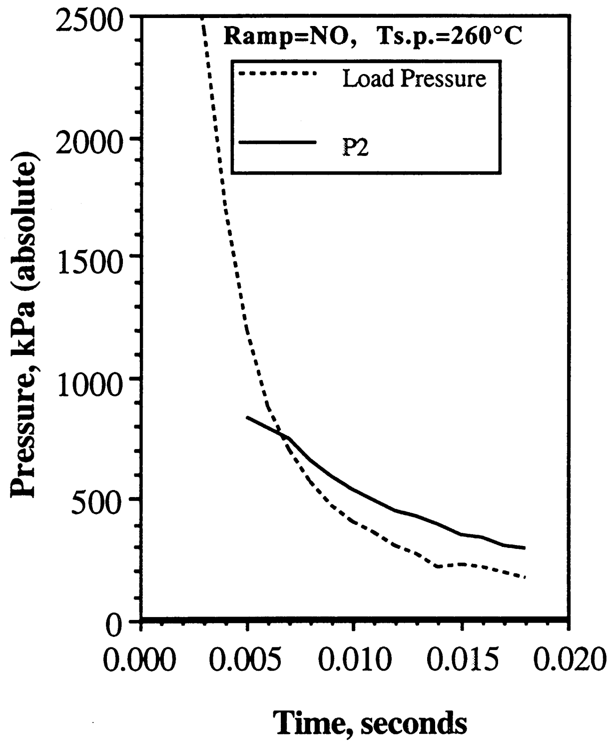

Figure 9. Sheet Pressure as Deduced from Measured Temperatures at Location 2 in the Sheet as a Function of Time During Nip Opening Using Ramp=NO at a Set-Point Temperature of 260°C.

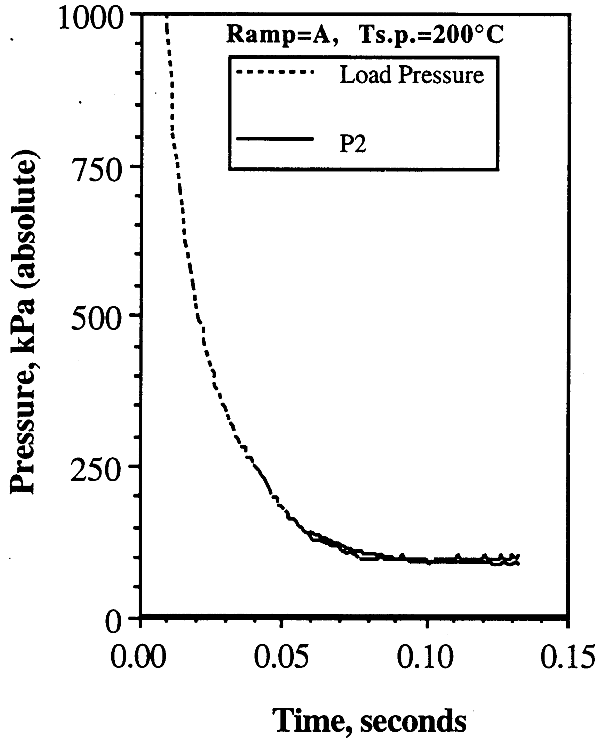

Figure 10. Sheet Pressure as Deduced from Measured Temperatures at Location 2 in the Sheet as a Function of Time During Nip Opening Using Ramp=A at a Set-Point Temperature of 200°C.

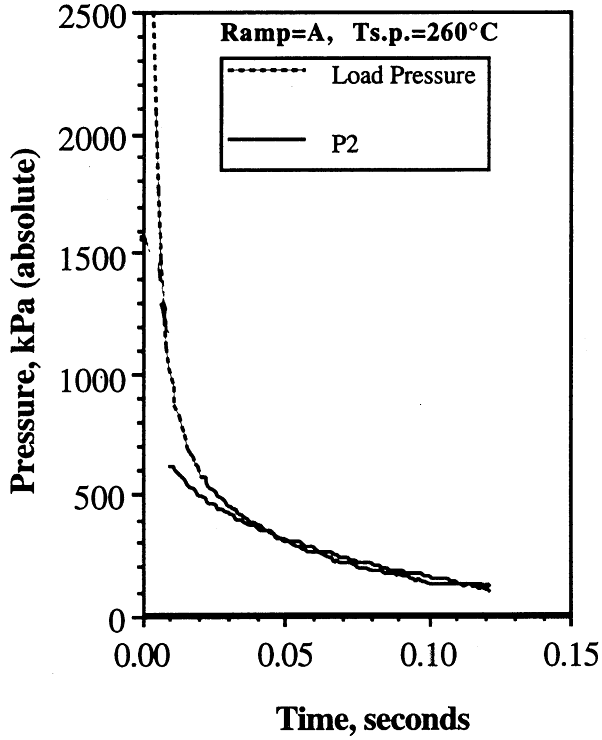

Figure 11. Sheet Pressure as Deduced from Measured Temperatures at Location 2 in the Sheet as a Function of Time During Nip Opening Using Ramp=A at a Set-Point Temperature of 260°C.